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CHAPTER 4.8
SCREW THREADS

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THREAD SYSTEMS

Figures 4.8.1 through 4.8.6 illustrate common thread forms.

The *unified national screw thread* (see Fig. 4.8.1) was adopted in 1948 as the preferred system for fasteners in the United States, Great Britain, and Canada. It is very similar to the earlier American standard system. Common designations are UNC (coarse), UNF (fine), UNEF (extra fine), and UNS (special).

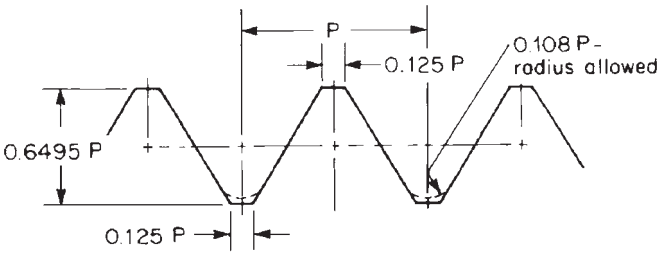

FIGURE 4.8.1 Unified national thread.

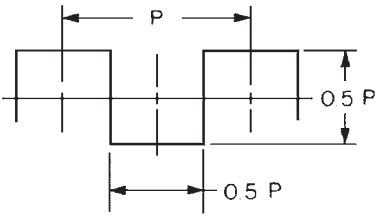

FIGURE 4.8.2 Square thread.

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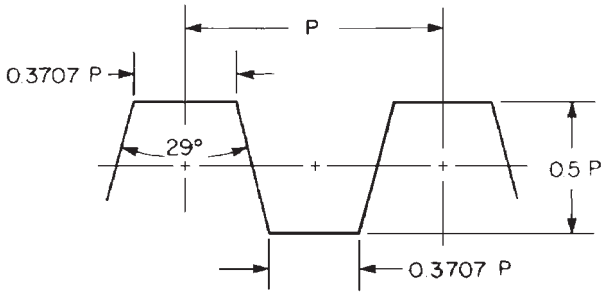

FIGURE 4.8.3 General-purpose Acme thread.

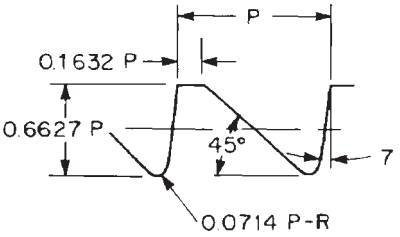

FIGURE 4.8.4 National buttress thread.

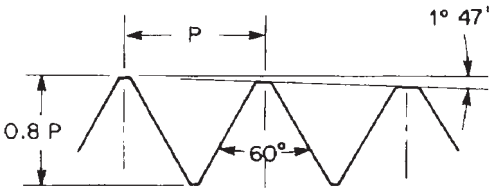

FIGURE 4.8.5 NPT pipe thread.

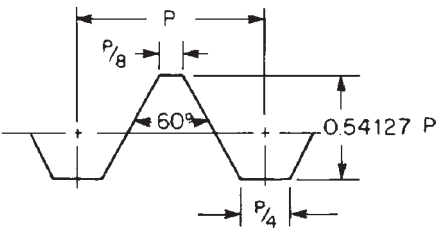

FIGURE 4.8.6 ISO metric thread.

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SCREW THREADS

There are three common thread classes in the unified system. Class 1 has the loosest fit and the broadest dimensional tolerances, Class 2 is the most common class for fasteners with closer fits and tolerances, and Class 3 is for more precise or critical applications. The letter *A* designates external threads and the letter *B* internal threads.

The standard method for designating a screw thread is to specify in sequence the nominal size, number of threads per inch, thread-series symbol, and thread-class symbol, supplemented optionally by pitch diameter and its tolerance. An example of an external thread designation and what it means is

$\frac{1}{4}$–20–UNC–3A
- 3A: thread-class designation
- UNC: thread-series designation
- 20: number of threads per inch (pitch)
- $\frac{1}{4}$: nominal size (in)

The *square thread form* (see Fig. 4.8.2) is the most efficient form for the transmission of power. However, it is more expensive to produce than other forms and has been largely superseded by the Acme thread form.

Acme threads (see Fig. 4.8.3) are also used for power transmission and are easier to manufacture than square threads, but their power-transmission capabilities are slightly lower. Some valve stems and many lead screws use this thread form.

Buttress threads (see Fig. 4.8.4) transmit power in one direction with virtually the full efficiency of a square thread but are relatively easily produced because of the tapered backside of the tooth form. They are used in military applications and when tubular members are screwed together.

American standard taper pipe thread (NPT), with the form shown in Fig. 4.8.5, is the standard thread for piping in the United States. *Straight* (nontapered) *pipe threads* and *dry-seal pipe threads* have similar forms.

The *ISO* (International Organization for Standardization) *metric screw thread* (see Fig. 4.8.6) is the prime metric screw thread for fasteners.

Standard nomenclature for thread forms is illustrated by Fig. 4.8.7. Coarse threads are suitable for general use, particularly in machines and other fastener applications in which quick and easy assembly is important. Fine threads are used when the design requires increased strength or reduced weight.

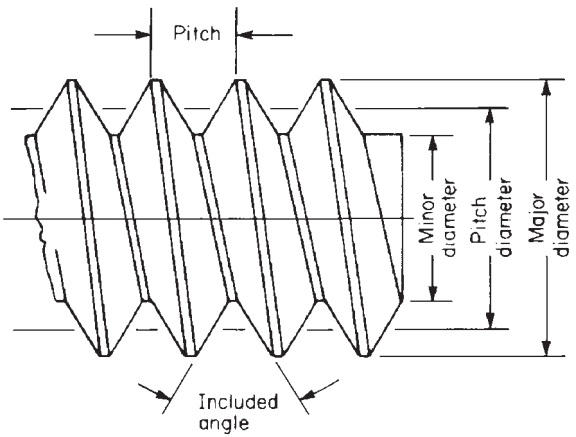

FIGURE 4.8.7 Standard nomenclature for screw-thread elements.

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In addition to fasteners—bolts, machine screws, setscrews, cap screws, and studs—and power applications (vises, clamps, fixtures, and screw jacks), screw threads are used to control position accurately as in machine lead screws and vehicle-steering mechanisms, to feed materials, and to change rotary to linear motion.

The size range of commercial screw threads is vast. Screw threads as small as 0.3 mm (0.012 in) in diameter and 140 threads per centimeter (360 per inch) are used in watches. At the other extreme, 600-mm (14-in) pipe is threaded with 8.5-mm-pitch (two threads per inch) pipe thread.

Self-tapping screws are used for wood, sheet metal, fiberboard, and other softer materials. The thread form differs from that used in machine screws and the shank is normally tapered. Figure 7.1.31 illustrates some typical self-tapping screws.

THREAD-MAKING PROCESSES: THEIR APPLICATIONS AND ECONOMICS

Hand Dies

An acorn or button die for external threads must be employed by hand; it is the least desirable of the methods that can be used to cut external threads. (See Fig. 4.8.8.) However, such dies can be used to advantage when a limited number of small-to medium-sized threads are to be cut and when accuracy of the thread lead in relation to the thread axis is not essential. Compared with other thread-making tooling, they are relatively inexpensive and easy to use.

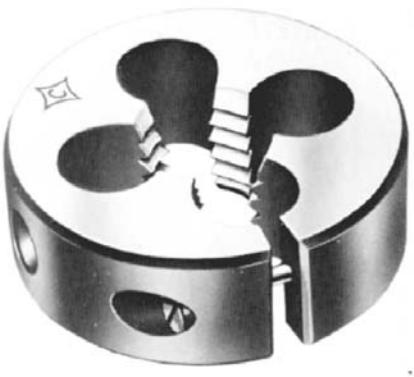

FIGURE 4.8.8 Button die for external threads. (*Courtesy Cleveland Twist Drill Co., subsidiary of Acme-Cleveland Corp.*)

Single-Point Threading

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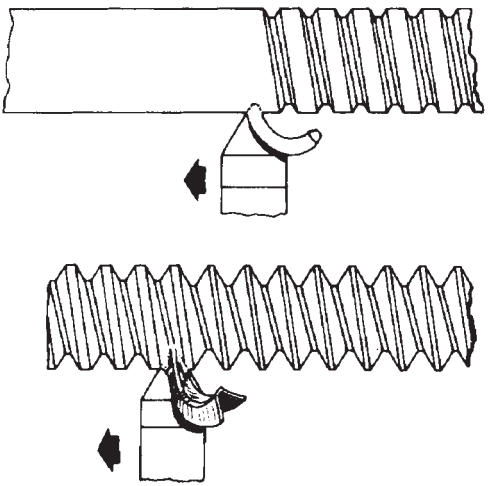

FIGURE 4.8.9 Single-point screw-thread cutting. (*Courtesy Teledyne Landis Machine.*)

With this method, a single-point tool having a profile corresponding to the profile of the thread is used as a means of generating the thread. Internal or external threads can be produced by this method. A lathe is used, and its carriage is moved longitudinally along the part by a lead screw that is gear-driven from the spindle. The lead screw moves the carriage and hence the tool at a rate exactly equal to the lead or pitch of the thread being produced. Generally, the thread is produced by making successive multiple passes. (See Fig. 4.8.9.)

Single-point threading is used more often when the workpiece is too large in diameter, the pitch too coarse, the material too difficult to machine, or the quantity too small to warrant using a die head. Holes as small as 8 mm ($^5/_{16}$ in) can be threaded by this method.

Thread-Cutting Die Heads

Die heads (not to be confused with thread-rolling heads) are an efficient and popular means of threading. They are versatile, have relatively wide ranges, and are made in a variety of models and sizes for application to many types of machines, including lathes, chuckers, multiple-spindle screw and threading machines, drill presses, and other types.

Die heads have four or five insert form cutters. When the head is fed axially from the end of the work, the threads are cut. Once engaged, the head is self-feeding at the rate of the thread lead. Cutter inserts can be removed for resharpening. Figure 4.8.10 illustrates a stationary, self-opening die head used with production lathes, chuckers, and screw machines.

Die heads can be used economically from low to moderate to high production levels depending on the circumstances. Compared with rolling, the blank need not have its diameter controlled as accurately because a certain amount of oversize can be trimmed away by the throat section of the chaser. Die-head chasers cost less than

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FIGURE 4.8.10 Stationary self-opening die head. (*Courtesy Teledyne Landis Machine.*)

thread rollers and usually can be salvaged if partially damaged. Setup for die-head cutting is also usually faster than for thread rolling.

Pipe-thread cutting is a common application for die heads.

Thread Milling

This process involves the use of a form-milling cutter that machines the thread form as

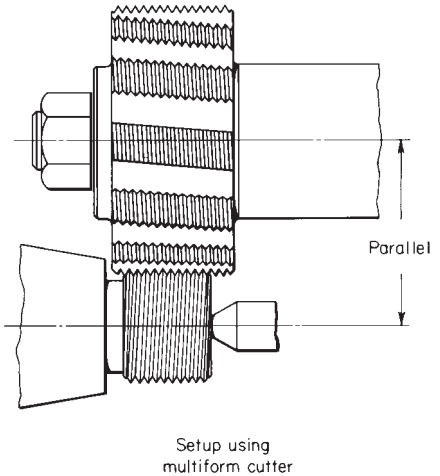

FIGURE 4.8.11 Thread milling. (*Courtesy Teledyne Landis Machine.*)

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the workpiece revolves. The most common type is the multiple-rib or multiple-form type, as shown in Fig. 4.8.11. Single-rib cutters are also used. With these, the workpiece must make as many revolutions as there are threads on the work.

Thread milling can be applied internally and externally and can be used to produce most thread forms regardless of whether they are straight or tapered. Minimum internal thread size is determined by the diameter of the cutter. Since interference is more pronounced because the cutter does not clear itself, the cutter normally should not exceed one-third of the hole diameter.

Thread forms that have flanks approaching 90° (to axis) are impossible to mill because the cutter cannot enter the cut without shaving the flank.

Some very coarse threads that are to be ground are rough-milled and then finished by grinding, possibly after a heat treatment.

Although thread milling is slower than die cutting, it is often necessary that a thread be milled because of coarse pitch, large or odd-shaped parts, a high helix angle, extremely long thread lengths, workpiece geometry, poor machinability of the workpiece material, or other considerations. As such, a single part or 10,000 pieces might be an economical production quantity.

FIGURE 4.8.12 Solid tap for cutting internal threads. (*Courtesy Teledyne Landis Machine.*)

Tapping

This process involves the use of a cylindrical form cutter, a tap, that has multiple cutting edges. The tap rotates and is fed axially into the work to produce internal threads. Both solid (Fig. 4.8.12) and collapsible (Fig. 4.8.13) taps are used. The operation can be carried out by hand or with drill presses, lathes, automatic screw machines, or special tapping machines.

Solid taps are used mainly to thread diameters ranging from 1.2 mm (0.047 in) to 150 mm (6 in). While the collapsible tap is limited by design factors on the low side to around 32-mm ($1\frac{1}{4}$-in) diameters, it is supplied for diameters as large as 600 mm (24 in). Solid taps are most economical in the 1.5-mm ($\frac{1}{16}$-in) to 50-mm (2-in) range. Although it is necessary to reverse the tap to back it out, in many cases the reversing operation can be done at much higher speed to reduce backout time.

Thread Grinding

Center-type grinding and centerless cylindrical grinding as described in Chaps. 4.13 and 4.14 are used in the production of some screw threads. Single- or multiple-rib-form wheels are employed with center-type grinding, while multiple-rib wheels are employed with centerless grinding. There is axial motion between the work and the wheel as the work rotates. Figures 4.8.14 and 4.8.15 illustrate the processes.

With center-type grinding, regardless of whether a single- or a multiple-rib wheel

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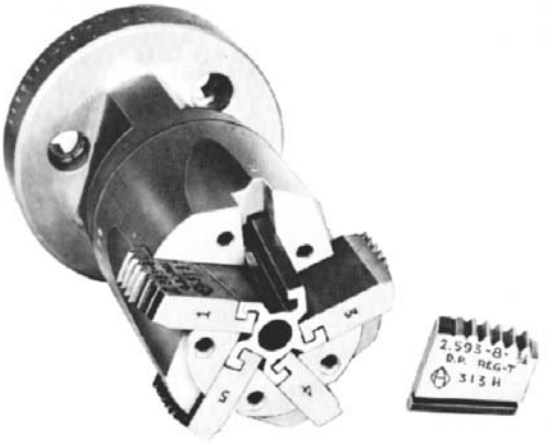

FIGURE 4.8.13 Collapsible tap. (*Courtesy Teledyne Landis Machine.*)

FIGURE 4.8.14 Center-type thread grinding. (*Courtesy Teledyne Landis Machine.*)

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SCREW THREADS

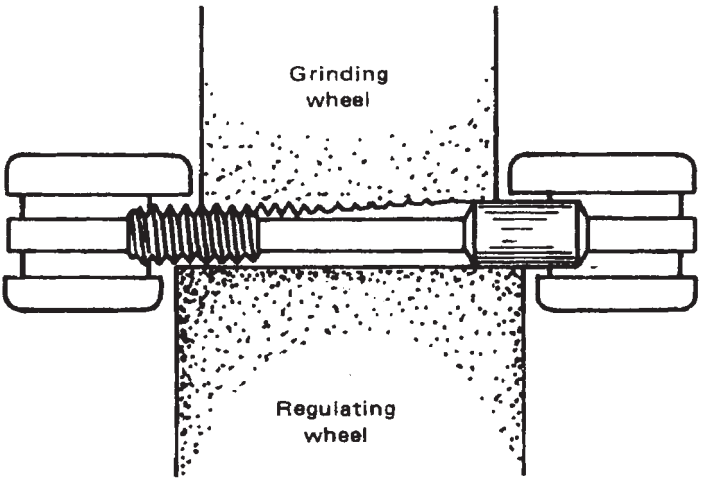

FIGURE 4.8.15 Centerless thread grinding. (*Courtesy Teledyne Landis Machine.*)

is used, the material specifications and the form, length, and quality of thread will determine the number of passes required to complete it. The number of passes can vary from one to five or six. With centerless grinding, the part is normally finished in one pass through the machine. As the work moves across the wheel, first it is sized to the correct diameter and then the threads are formed.

Threaded parts that are ground include those which are too hard to cut, mill, or roll, when a fine finish is required or when precision form, lead, and pitch requirements must be held before and, most particularly, after hardening. Forms that are produced include API, NPT, and other taper pipe threads, 60° unified and metric, 55° Whitworth, 29° and 40° worm, 47°30″ British Association, 53°8″ Lowenhertz, Buttress, and others.

Centerless-ground threaded parts include continuous threaded parts such as setscrews, studs, threaded bushings, threaded size-adjusting bushings for boring heads, thread gauges, worm gears, powdered-iron screws, and self-threading insert bushings.

Materials that can be thread-ground include hardened and annealed screw stock, the alloyed high-speed tool and stainless steels, and sintered iron. The last-named is used widely for continuously threaded screws.

Center-type thread grinders are applicable to short as well as long production runs. Single-rib grinding wheels are more applicable to low production quantities and multi-rib wheels to mass production.

Setup times for hand operation range from ½ to 1 h and, for automatic operation, from 1½ to 2 h.

Centerless thread grinding is used for high production quantities. On diameters 10 mm (⅜ in) and larger, moderate quantities of 10 to 15,000 make for economical setups and reasonable runs. When grinding diameters smaller than 10 mm, particularly when diameter and length are the same or the length is up to 1½ times the diameter, the quantity should exceed 15,000. On the smaller diameters, the setup is proportionally harder and takes longer. However, the production rate is higher than on the larger diameters. It is possible to run a ¼-in, 20-pitch, 1¼-mm-long setscrew at 7500 pieces

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per hour.

Thread Rolling

Thread and form rolling is accomplished by having hardened-steel dies penetrate round blanks. The exertion of adequate force displaces the material into the voids and produces a form the reverse of that on the die. Figure 4.8.16 shows the process schematically when flat dies are used. The main advantages of rolled threads over threads produced by other manufacturing processes are that they have improved physic a l

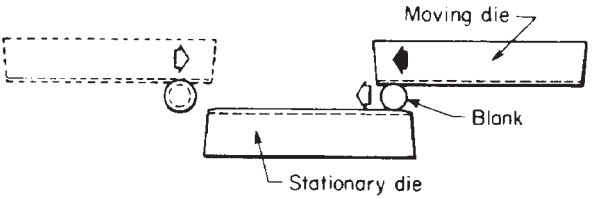

FIGURE 4.8.16 Thread rolling with flat dies. (*Courtesy Teledyne Landis Machine.*)

characteristics, greater accuracy, and a high degree of surface finish. Another advantage is that there is no waste, since no material is removed in the formation of the thread.

With regard to the physical characteristics of a rolled thread, there is a substantial increase in the tensile and shear strengths and resistance to fatigue. When a thread is produced by other manufacturing processes, the grain fibers of the metal are severed in the formation of the thread. However, when a thread is rolled, the grain fibers are made to flow in continuous unbroken lines following the contour of the thread. This is shown in Fig. 4.8.17.

Thread rolling is accomplished with reciprocating flat-die rolling machines, machines of the cylindrical-die type, thread-rolling heads, thread-rolling attachments, single-bump rolling equipment, and planetary rolling machines. Because the workpiece diameter before thread rolling should be controlled accurately, centerless grinding sometimes precedes the operation.

In addition to straight and taper threads, such forms as oil grooves and worm and gear forms are produced routinely by cold forming on thread-rolling machines. Sometimes, however, the geometry of the part is not conducive to thread-rolling applications. Figure 4.8.18 presents illustrations of typical parts that have had threads and other forms produced by the rolling process.

In comparison with a cutting tool that is less expensive, tends to wear quickly, but can be easily reground, the roll set is more expensive, may or may not be regrindable, and must produce more parts to justify its cost. Therefore, the rolling process generally must be matched to longer runs or to cases in which extra tool cost can be amortized. In some cases, when the necessary rolling die is available and can be substituted for a thread-cutting head, rolling may be economical for moderate-sized lots. Thread-rolling dies have a long life (from tens of thousands to millions of pieces), and resharpening during the life of the die is not necessary.

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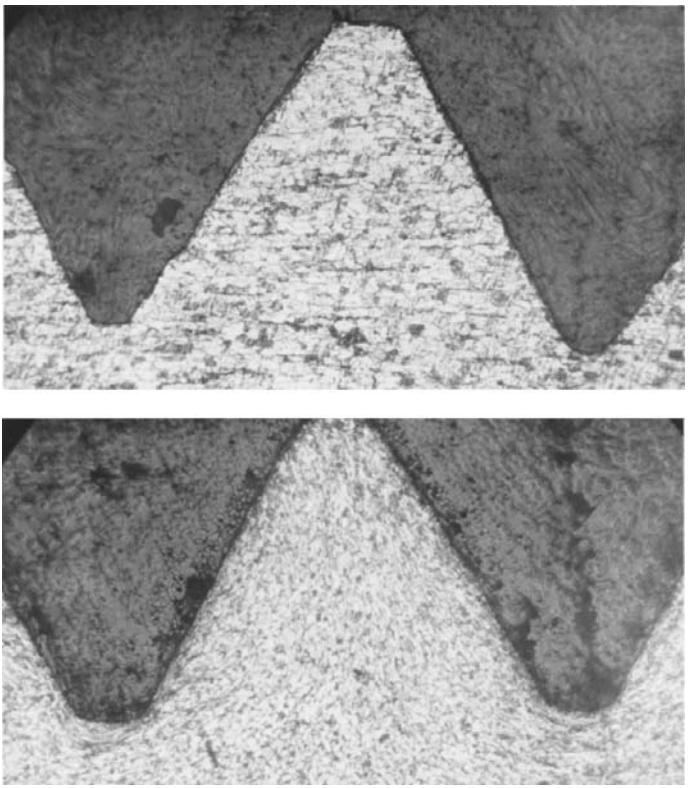

FIGURE 4.8.17 Grain structure of cut threads (*a*) contrasted with the stronger, plastically deformed structure of rolled threads (*b*). (*Courtesy Teledyne Landis Machine.*)

Cold-Form Tapping

Forming taps produce internal screw threads by plastic flow of material near the hole walls rather than by metal removal, as with conventional cutting taps. Figure 4.8.19 illustrates a typical forming tap.

The method has the advantages that no chips are formed, that the threads are strong, and that tapping speeds are higher. However, only a limited range of soft, ductile materials is suitable for cold-form tapping, and the percentage of thread is best held to 65 percent or less to avoid overfilling at the minor diameter. Torque requirements for tapping are also higher than for cutting taps. The characteristic thread form has a small groove at the crest of the thread, the width of which decreases with higher percentages of thread.

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FIGURE 4.8.18 Typical parts with rolled threads. (*Courtesy Teledyne Landis Machine.*)

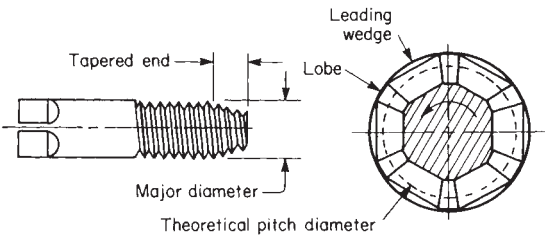

FIGURE 4.8.19 Cold-forming tap. (*From American Machinist.*)

SUITABLE SCREW-THREAD MATERIALS

Cut Threads

Often, the end use of the workpiece or considerations other than the threading operation dictate the selection of the material. However, when a choice is possible, selecting

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one of the free-cutting grades of material will give a more accurate thread of smoother finish. Compared with threading non-free-machining grades, producing a thread on free-cutting material will result in higher production at lower machining and tool costs. Soft, non-free-machining metals are especially difficult to thread, for they produce stringy chips that weld to the cutting edge.

In many cases metals selected on the basis of cost are more expensive in the end. A proportionately greater amount of time is spent obtaining a satisfactory thread. Also, higher tool cost is involved, tool life is poorer, and more downtime is required for tool changes.

Materials suitable for threading follow generally those suitable for most machining operations. Brasses and bronzes cut better and at higher speed than steels, free-machining steels cut better than unleaded or non-free-machining grades, and as carbon content increases and/or additives such as chromium or molybdenum are introduced, machinability drops quite rapidly. Aluminum, in bar stock, is generally quite good, but cast aluminum can be quite abrasive and cause excessive tool wear. Cast iron is brittle and presents a problem of maintaining a good form on the crest of the thread. Low-carbon steels, such as the 1010 and 1020 grades, while soft enough for easy machining, tend to tear, and it is difficult to obtain a good finish.

In steels, it is difficult to cut good threads when the Brinell hardness is below 160. This is due mainly to the difficulty in breaking the chip in such soft steel. In harder materials, the chip can be broken more easily. Easier breaking causes less interference at the cutting face of the tool and allows freer cutting and a smoother finish. Materials above R_c 34 are usually not suitable for die chasers and taps, which, generally speaking, are manufactured from high-speed steels. The single-point process using carbide is better suited for materials above R_c 34.

Difficult-to-machine materials sometimes can be more advantageously threaded by thread milling. In setting speeds and feeds, consideration must be given to the workpiece hardness and cutter material, taking into account the fact that 60° thread forms do not make for a cutter with strong teeth.

Ground Threads

Materials generally suitable for other form-grinding operations are satisfactory also for ground threads. The most suitable materials are the hardened steels and any metals that will be heat-treated above R_c 33 before threading. Aluminum and comparable soft materials are the most difficult to grind because they tend to load the wheel and cause burning.

Formed Threads

Different properties are required for thread forming than for cutting, and materials that can be cut may not be suitable for thread rolling or cold-form tapping. Factors that promote thread formability are low hardness, a low yield point, elongation of 12 percent or more, a fine-grained microstructure, and freedom from work hardening.

Leaded and sulfurized steel and leaded brasses do not work out well for thread rolling and should be considered only for cut threads. The use of thread rolling is also generally not recommended for materials that exceed R_c 32 hardness. With materials harder than this, die life is substantially reduced. Table 4.8.1 indicates the rollability and expectable die life for commonly thread-rolled metals.

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TABLE 4.8.1 Rollability of Materials: Rolled-Thread Finish and Proportional Die Life*

Standard designation	UNS designation	Thread finish	Proportional die life: Soft	Proportional die life: R_c 5–24	Proportional die life: R_c 25–32	Proportional die life: R_c 33 and over	Remarks
Carbon and alloy steels							
1008–1095	G10080–G10950	E	H	H–M	M	L	Excellent rollability.
1108–1151	G11080–G11510	G	H	H–M	M		These are free-machining steels with high sulfur content. The highest sulfer materials, 1119, 1144, and 1200 Series, should be avoided when possible.
1211–1215	G12110–G12150	F	M				
1111–1113	G11110–G11130	F	H				
1330–1345	G13300–G13450	E	H	M	M–L	L	These are medium-alloy steels with alloys such as manganese, molybdenum, chromium, and nickel. Work hardening of material requires higher pressures, and some reduction in roll life over the 1000–1200 Series will be experienced.
4118–4161	G41180–G41610	E	H–M	M	M–L	L	
4320–4340	G43200–G43400	E	H–M	M	M–L	L	
4815–4820	G48150–G48200	E	H–M	M	M–L	L	
5115–5160	G51150–G51600	E	H-M	M	M-L	L	
6118–6150	G61180–G61500	E	H–M	M	M–L	L	
8720–8740	G87200–G87400	E	H–M	M	M–L	L	
9255–9260	G92550–G92600	E	H–M	M	M–L	L	
Stainless steels							
302–304	S30200–S30400	E		M–L	L		These are nonhardenable austenitic steels containing higher quantities of nickel and chromium. High work hardening occurs with percent alloy. They are also nonmagnetic. Material does not seam.
305, 321	S30500, S32100	E		M	L		
347, 348	S34700, S34800	E		M	L		
329, 430F	S32900, S43020	E		M–L	L		Nonhardenable ferritic chromium stainless, but magnetic.
446	S44600	E		M–L	L		

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430–443	S43000–S44300	E	M	L	Lower work hardening but higher pressures required owing to carbon.
414, 420F	S41400, S42020	E	M–L	L	Hardenable martensitic chromium steels; magnetic. They are the best suited for rolling of the stainless grades; low work hardening.
440F	S44020	E	H–M	L	
410, 431	S41000, S43100	E	H–M	L	
440C	S44004	E	H–M	L	

Wrought copper and copper alloys

Material designation	Alloy name	Maximum hardness	Finish	Die life	Remarks
C10200	Oxygen-free copper	RF40	E	H	More than 90% copper; excellent rollability.
C11000	Electrolytic copper (ETP)	RF40	E	H	
C21000	Gilding, 95%	RB40	E	H	Copper-zinc alloys basically good for rolling except when zinc exceeds 30%. This tends to produce poor finish as indicated in C27000–C28000.
C23000	Red brass, 85%	RB55	E	H	
C26000	Cartridge brass, 70%	RB60	E	H	
C27000	Yellow brass, 65%	RB55	F	H	
C31400	Leaded commercial bronze	RB65	P	M-H	Copper-zinc alloys with lead added for improved machining characteristics; poor to fair for rolling. Higher lead produces poorer thread finish and is not recommended for rolling
C33500	Low-leaded brass	RB60	G	M-H	
C34200	High-leaded brass, 64½%	RB55	P	M	
C34500	Thread-rolling brass	RB75	G	M-H	
C36000	Free-cutting brass	RB70	P	L	
C37000	Free-cutting Muntz metal	RB70	P	L	
C38500	Architectural bronze	RB65	P	L	
C44300–C44500	Admiralty brasses	RB75	E	H	Copper-zinc alloy with 1.0% tin; excellent rollability.
C46400, C46500	Naval brass	RB75	P-F	M	Copper-zinc alloy with lead and tin not conducive to good rolling characteristics. Alternative material should be used.
C48500	Naval brass, high-leaded	RB80	P	L	
C50200	Phosphor bronze E	RB50	G	H	Copper-tin alloy generally good for rolling, but increasing tin content reduces rollability. C54400 contains some lead and zinc, thereby reducing rollability
C51000	Phosphor bronze A	RB65	G	H	
C54400	Phosphor bronze B-2	RB70	P	L	

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TABLE 4.8.1 Rollability of Materials: Rolled-Thread Finish and Proportional Die Life* (*Continued*)

Wrought copper and copper alloys					
Material designation	Alloy name	Maximum hardness	Finish	Die Life	Remarks
C65100	Low-silicon bronze B	RB70	E	M	Copper with silicon as basic alloy; average rollability
C65500	High-silicon bronze A	RB75	FG	M	
C67500	Manganese bronze A	RB70	P	M	High-zinc alloy; alternative material should be used.
C70600	Copper-nickel 10%	RB70	G	M–H	High-nickel alloy; reduce rollability proportionally.
C74500	Nickel-silver, 65-10	RB70	E	H	Copper with zinc and nickel as alloy; rollability good to excellent. As alloy increases, rollability \ decreases.
C75200	Nickel-silver, 65-18	RB70	G–E	H	

Annealed copper casting alloys
With regard to the rollability of copper casting alloys in the annealed condition, most are rated as having poor rollability and poor die life. Copper alloys with basic quantities of tin, zinc, or silicon rate slightly better in die life, with poor to fair finish. It is recommended that these materials be avoided when possible and be considered only for low production quantities.

Wrought aluminum and aluminum alloys							
Material designation							
SAE no. & temper	UNS no.	Condition	Maximum hardness	% Elongation	Finish	Die life	Remarks
1100–0	A91100	Annealed	RB23	45	E	H	99% aluminum recommended for rolling. Work-hardens very slowly; cannot be heat-treated. Major alloy is silicon.
1100–HI4	A91100	Half hard	RB32	20	G–E	H	
1100–HI8	A91100	Full hard	RB44	15	FG	M	
2011–T3	A92011	Heat-treated and cold-worked	RB95	15	FG	M–H	Lower-quality finish is a result of lead and bismuth alloys; not generally recommended for rolling.
2011–T6	A92011	Heat-treated and aged	RB97	17	F	M–H	

2014–0	A92014	Annealed	RB45	18	G	M–H	Copper, silicon, and manganese major alloys; higher strength requires greater roll pressure.
2014–T4	A92014	Heat-treated and aged	RB105	20	G–E	M–H	
2017–0	A92017	Annealed	RB45	22	E	H	Good rollability; most commonly used for rolling.
2017–T4	A92017	Heat-treated and aged	RB105	22	E	H	
2024–0	A92024	Annealed	RB47	22	E	H	
2024–T3	A92024	Heat-treated and cold-worked	RB120	18	E	H	
3003–0	A93003	Annealed	RB28	40	E	H	99% aluminum recommended for rolling; work-hardens very slowly; cannot be heat-treated. Major alloy is manganese.
3003–H14	A93003	Half hard	RB40	16	G	H	
3003–H18	A93003	Full hard	RB55	10	P–F	L–M	
5052–0	A95052	Annealed	RB47	30	E	H	Fair to good rollability in the lower-hardness condition; major alloy manganese with chromium.
5052–H34	A95052	Half hard	RB68	14	F	M	
5056–0	A95056	Annealed	RB65	35	E	H	Major alloy magnesium; recommend rolling in annealed condition only.
5056–H18	A95056	Strain-hardened	RB105	10	P	L–M	
061–0	A96061	Annealed	RB30	30	E	H	Good to excellent rollability in conditions.
6061–T4	A96061	Heat-treated and aged	RB25	65	G–E	H	
7075–0	A97075	Annealed	RB60	16	F	H	Generally not recommended for rolling.
7075–T6	A97075	Heat-treated and aged	RB150	11	P	M	
Wrought nickel and nickel alloys							
The nickel alloys in general can be produced with a good to excellent thread finish. The Inconel and Hastelloy series result in a poor to fair finish. The higher tensile strength of nickel alloys requires high roll pressures, and therefore, medium to low die life can be expected. It is recommended that annealed material be used whenever possible.							

*Letter designations for finish: E, excellent; G, good; F, fair; P, poor. Letter designations for die life: H, high; M, medium; L, low. Elongation factor: generally acceptable results can be achieved when percent elongation equals 12 or more.

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Cold-form tapping requires even greater cold workability than external-thread rolling. Cold-workable grades of brass, copper, and aluminum and low-carbon steel are the most commonly used materials.

DESIGN RECOMMENDATIONS FOR SCREW THREADS

External threads made by all processes should not terminate too close to a shoulder or other larger diameter. Space must be provided for the thread-cutting tool. In fact, there should be an area of thread relief or undercut where the diameter of the workpiece is less than the minor thread diameter. (See Fig. 4.8.20.) This allows room for the throat

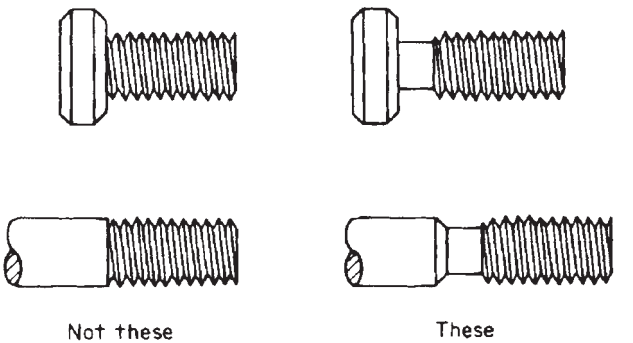

FIGURE 4.8.20 Allow thread relief at the end of the threaded length.

angle of the thread cutter, which would otherwise produce an incomplete thread at the end. It also reduces the chance of tool breakage. The width of this relief depends on the size of the part, coarseness of the thread, and throat angle of the threading tool. From 1.5 mm ($\frac{1}{16}$ in) to 19 mm ($\frac{3}{4}$ in) or more should be allowed. When possible, the width of the relief should be increased to allow use of chasers having the maximum length of the throat or chamfer. This will provide maximum efficiency of the operation and maximum tool life.

Internal threads should have a similar relief or undercut even though, for blind holes, it necessitates an added recessing operation before threading. Blind holes, even if not provided with an undercut, require some unthreaded length at the bottom for chip clearance. Best and most economical of all is the through hole, which provides both chip clearance and relief if the threads extend to the opposite surface. Figure 4.8.21 illustrates these alternatives.

In many applications no more than 60 or 65 percent of the thread height is required for adequate thread strength. Threads in this range machine more easily, requiring only 75 percent of the torque needed for conventional threads. If high strength is not required, consider the use of a reduced-height thread form. (See Fig. 4.8.22.)

Similarly, the length threaded should be kept as short as possible consistent with the functional requirements of the part. Shorter threads machine more quickly and provide longer tool life. For internal threads, where tap breakage may be a problem, limit the depth of the threaded portion to two diameters.

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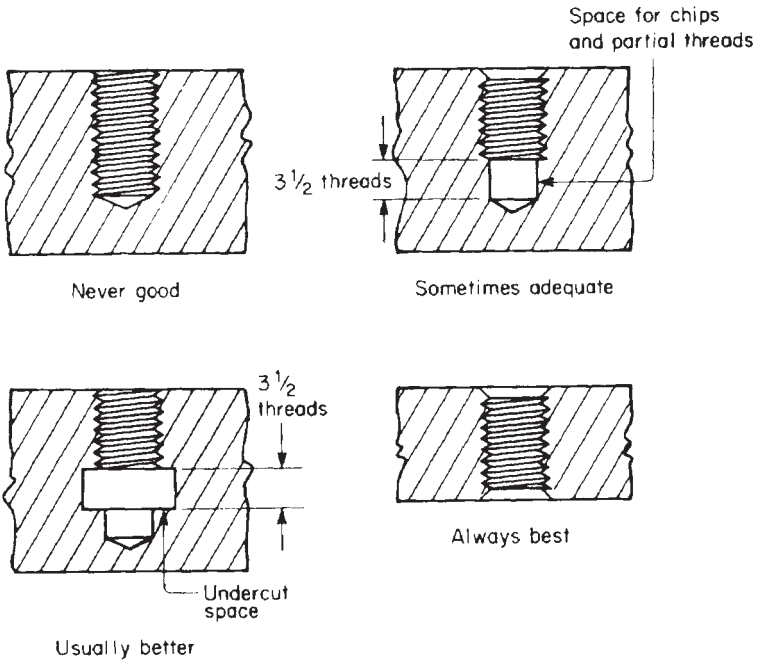

FIGURE 4.8.21 Allow chip clearance with internal threads.

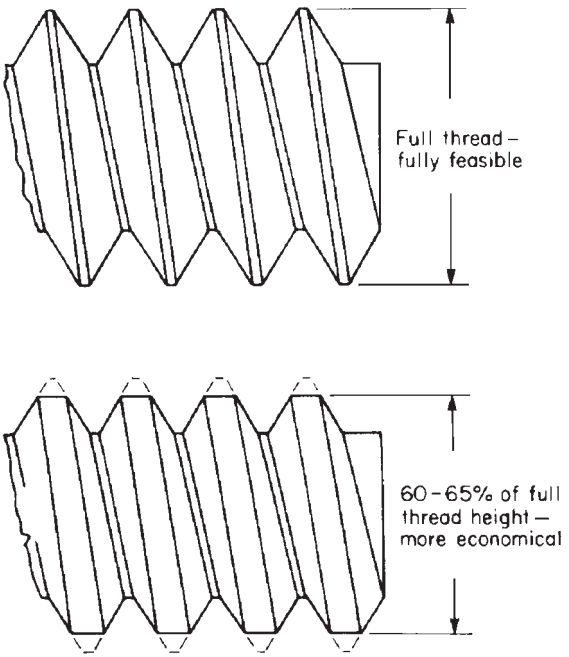

FIGURE 4.8.22 A reduced-height-thread form will machine more easily than a full thread and has adequate strength for most applications.

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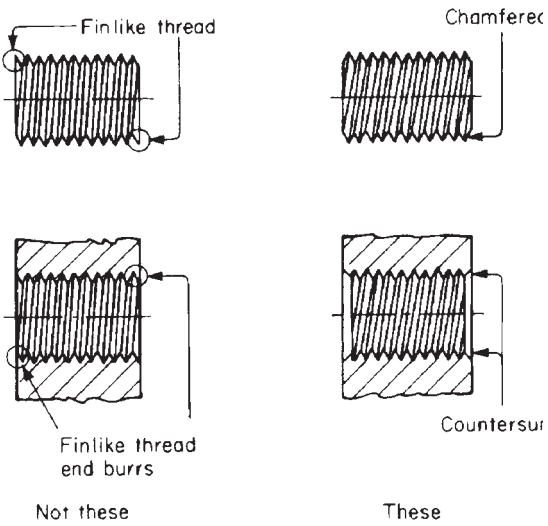

FIGURE 4.8.23 Specify chamfers and countersinks at the ends of threaded sections.

The design of threaded products should include a chamfer at the ends of the external threads and a countersink at the ends of the internal threads. These inclined surfaces prevent the formation of finlike threads at the ends, help to minimize burrs, and assist the threading tool in starting to cut or form the threads. (See Fig. 4.8.23.)

Aside from chamfers and countersinks, the surface at the starting end of the screw thread should be flat and square with the thread's center axis. Otherwise, proper starting of the thread-making tool may be difficult.

Slots, cross holes, and flats should not be placed where they intersect screw threads. Most thread-making processes are adversely affected by surface interruptions, and burrs are almost inevitable where the surfaces intersect. Burrs on thread surfaces are especially costly to remove. When cross holes are unavoidable, they should be countersunk.

Standard thread forms and sizes with off-the-shelf threading tools are always more economical than threads made with special tools.

Tubular parts must have a wall heavy enough to withstand the pressure of the cutting or forming action. This stricture applies to both internal and external threads. Castings and forgings of odd shapes should not have thin sections at a portion of the thread's circumference. Otherwise, out-of-roundness will occur.

Tolerances closer than required for the given function should not be specified. Class 2 threads are usually satisfactory for most work.

Threads to be ground should not be specified to have sharp corners at the root. Normally, a radius of 0.08 mm (0.003 in) is the very minimum that can be expected, and much larger radii on the order of 0.25 mm (0.010 in) are preferable. (See Fig. 4.8.24.)

Centerless-ground threads should have a length-to-diameter ratio of at least 1:1, but preferably the length should be longer than the diameter. Parts to be centerless-thread-ground also should not have large burrs, be flattened or egg-shaped from shearing, or be bent or crooked. Taper and flatness also should be avoided because they will not be removed by the thread-grinding operation.

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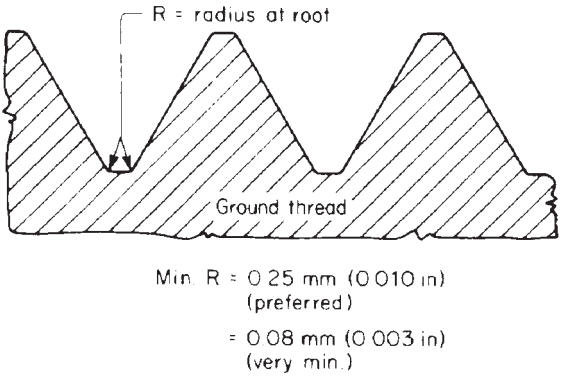

FIGURE 4.8.24 Ground threads require a generous root radius.

Parts for thread rolling have similar requirements of roundness, straightness, and freedom from taper and burrs. Uniformity of hardness is also important for thread rolling, as is accurate blank diameter.

Except for the largest sizes, coarse threads are slightly more economical to produce than fine threads and should be specified in preference to fine threads if the part's function permits. Coarse threads also assemble more rapidly.

DIMENSIONAL FACTORS AND TOLERANCES

The same factors induce dimensional variations in screw threads as affect the dimensions of other types of surfaces produced by thread-making equipment. The accuracy and conditions of tooling and equipment are key factors for all thread-making processes. So are the skill of the worker, the suitability of the material, and the feed rate of the threading tool.

When conditions are optimal and extra care and extra time (sometimes considerable) are taken, Class 4 and 5 threads can be produced by all the methods covered by this chapter. Suitably accurate measuring equipment is also required to guide and control the accuracy of the final results.

Hand dies are normally not capable of the highest precision and are primarily applicable to Class 1 and 2 threads only. Other thread-cutting methods can be used for Classes 1 through 5, with costs increasing sharply at the higher precision levels. Best lead accuracy occurs when the advance of the thread-cutting tool is controlled by lead screw rather than by the tap or die. Surface finishes smoother than 1.6 μm (63 μin) are not normally attainable by thread cutting.

With thread milling, by using a careful setup and moderate feed, the outside, pitch, and root diameters can be held to ±0.025 mm (0.001 in). Lead depends on the accuracy of the lead screw of the machine and can be held as close as 0.001 mm/cm (0.0001 in/in). Surface finish can be held to 1.6 μm (63 μin), with finer finishes sometimes possible with finer feed. Thread milling is a suitable method for accurate classes of thread, especially if the workpiece material has some machinability limitations.

At one time, thread grinding was essential to achieve Class 4 and 5 threads. This circumstance has changed, and Class 5 threads are now both rolled and cut. Grinding

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is used most frequently when the hardness of workpiece precludes other methods. If finishes and accuracy greater than those specified for Class 3 threads are required, reduced production rates should be expected. Center-type grinders can hold flank angles of thread forms to $\pm 1/4°$ and lead accuracy to within ± 0.002 mm/cm (0.0002 in/in) and the cumulative error to not more than 0.06 mm in 300 mm (0.0024 in/ft).

All classes of thread can be rolled. The piece-to-piece accuracy of rolled threads depends on various factors, particularly the consistency of the blank diameter and the uniformity of material and structure from piece to piece. Tolerances cannot be met if there are variations in these factors. Centerless grinding is a common preliminary operation to thread rolling to ensure an accurate blank diameter. The surface finish of rolled threads is superior to that of cut threads or about as smooth as the surface of the rolling dies. Generally, a limit of 0.8 μm (32 μin) can be specified if a smooth surface is required.

Tables 4.8.2 and 4.8.3 provide information on the approximate dimensions and tolerances of standard screw threads. Additional data on screw-thread dimensions and tolerances can be found in the publication *Screw Thread Standards for Federal Services,* Handbook H28, published by the U.S. Department of Commerce. A similar publication is *Unified Inch Screw Threads* (ANSI B1.1-1974), published by the American National Standards Institute.

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TABLE 4.8.2 Dimensions and Tolerances for Unified and National Threads

			Tolerances, in											
			Major diameter external threads†			Pitch diameter‡							Minor diameter,§ internal threads	
Sizes*	Basic major diameter, in, D	Threads per inch, n	Class 1A	Classes 2A and 3A	Classes 2 and 3	Class 1A	Class 1B	Class 2A	Class 2B	Class 3A	Class 3B	Class 2	Class 3	Classes 1B, 2B, and 3B	Classes 2 and 3
Fine-pitch threads															
0 (0.060)	0.0600	80		0.0032	0.0034			0.0018	0.0023			0.0017	0.0013	0.0049	0.0049
1 (0.073)	0.0730	72		0.0035	0.0036			0.0019	0.0025			0.0018	0.0013	0.0055	0.0054
2 (0.086)	0.0860	64		0.0038	0.0038			0.0020	0.0027			0.0019	0.0014	0.0062	0.0055
4 (0.112)	0.1120	48		0.0045	0.0044			0.0024	0.0031			0.0022	0.0016	0.0074	0.0066
6 (0.138)	0.1380	40		0.0051	0.0048			0.0026	0.0034			0.0024	0.0017	0.0077	0.0070
8 (0.164)	0.1640	36		0.0055	0.0050			0.0028	0.0036			0.0025	0.0018	0.0077	0.0063
10 (0.190)	0.1900	32		0.0060	0.0054			0.0030	0.0039			0.0027	0.0019	0.0079	0.0062
12 (0.216)	0.2160	28		0.0065	0.0062			0.0032	0.0042			0.0031	0.0022	0.0084	0.0062
¼	0.2500	28	0.0098	0.0065	0.0062	0.0050	0.0065	0.0033	0.0043	0.0025	0.0032	0.0031	0.0022	0.0077	0.0060
⅜	0.3750	24	0.0108	0.0072	0.0066	0.0057	0.0074	0.0038	0.0049	0.0029	0.0037	0.0033	0.0024	0.0073	0.0065
½	0.5000	20	0.0122	0.0081	0.0072	0.0064	0.0084	0.0043	0.0056	0.0032	0.0042	0.0036	0.0026	0.0078	0.0072
¾	0.7500	16	0.0142	0.0094	0.0090	0.0775	0.0098	0.0050	0.0065	0.0038	0.0049	0.0045	0.0032	0.0085	0.0080
1	1.0000	12	0.0172	0.0114	0.0112	0.0088	0.0114	0.0059	0.0076	0.0044	0.0057	0.0056	0.0040	0.0100	0.0090
1¼	1.2500	12	0.0172	0.0114	0.0112	0.0092	0.0120	0.0062	0.0080	0.0046	0.0060	0.0056	0.0040	0.0100	0.0090
1½	1.5000	12	0.0172	0.0114	0.0112	0.0096	0.0125	0.0064	0.0083	0.0048	0.0063	0.0056	0.0040	0.0100	0.0090
Coarse-pitch threads															
1 (0.073)	0.0730	64		0.0038	0.0038			0.0020	0.0026			0.0019	0.0014	0.0062	0.0062
2 (0.086)	0.0860	56		0.0041	0.0040			0.0021	0.0028			0.0020	0.0015	0.0070	0.0070
4 (0.112)	0.1120	40		0.0051	0.0048			0.0025	0.0033			0.0024	0.0017	0.0090	0.0089
6 (0.138)	0.1380	32		0.0060	0.0054			0.0028	0.0037			0.0027	0.0019	0.0098	0.0103
8 (0.164)	0.1640	32		0.0060	0.0054			0.0029	0.0038			0.0027	0.0019	0.0087	0.0082
10 (0.190)	0.1900	24		0.0072	0.0066			0.0033	0.0043			0.0033	0.0024	0.0106	0.0110
12 (0.216)	0.2160	24		0.0072	0.0066			0.0034	0.0044			0.0033	0.0024	0.0098	0.0092
¼	0.2500	20	0.0122	0.0081	0.0072	0.0056	0.0073	0.0037	0.0048	0.0028	0.0036	0.0036	0.0026	0.0108	0.0101

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TABLE 4.8.2 Dimensions and Tolerances for Unified and National Threads (*Continued*)

			Tolerances, in												
			Major diameter external threads†			Pitch diameter‡								Minor diameter,§ internal threads	
Sizes*	Basic major diameter, in, *D*	Threads per inch, *n*	Class 1A	Classes 2A and 3A	Classes 2 and 3	Class 1A	Class 1B	Class 2A	Class 2B	Class 3A	Class 3B	Class 2	Class 3	Classes 1B, 2B, and 3B	Classes 2 and 3
			Coarse-pitch threads (*Continued*)												
⅜	0.3750	16	0.0142	0.0094	0.0090	0.0065	0.0085	0.0044	0.0057	0.0033	0.0043	0.0045	0.0032	0.0109	0.0111
½	0.5000	13	0.0163	0.0109	0.0104	0.0074	0.0097	0.0050	0.0065	0.0037	0.0048	0.0052	0.0037	0.0117	0.0123
½	0.5000	12	0.0172	0.0114		0.0077	0.0100	0.0051	0.0066	0.0038	0.0050			0.0125	
¾	0.7500	10	0.0194	0.0129	0.0128	0.0088	0.0115	0.0059	0.0077	0.0044	0.0057	0.0064	0.0045	0.0128	0.0136
1	1.0000	8	0.0225	0.0150	0.0152	0.0101	0.0132	0.0068	0.0088	0.0051	0.0066	0.0076	0.0054	0.0150	0.0148
1¼	1.2500	7	0.0246	0.0164	0.0170	0.0111	0.0144	0.0074	0.0096	0.0055	0.0072	0.0085	0.0059	0.0171	0.0154
1½	1.5000	6	0.0273	0.0182	0.0202	0.0121	0.0158	0.0081	0.0105	0.0061	0.0079	0.0101	0.0071	0.0200	0.0180
2	2.0000	4½	0.0330	0.0220	0.0254	0.0143	0.0186	0.0095	0.0124	0.0071	0.0093	0.0127	0.0089	0.0267	0.241
2½	2.5000	4	0.0357	0.0238	0.0280	0.0155	0.0202	0.0104	0.0135	0.0078	0.0101	0.0140	0.0097	0.0300	0.0270
3	3.0000	4	0.0357	0.0238	0.0280	0.0161	0.0209	0.0107	0.0139	0.0080	0.0104	0.0140	0.0097	0.0300	0.0270
3½	3.5000	4	0.0357	0.0238	0.0280	0.0166	0.0215	0.0110	0.0143	0.0083	0.0108	0.0140	0.0097	0.0300	0.0270
4	4.0000	4	0.0357	0.0238	0.0280	0.0170	0.0221	0.0113	0.0147	0.0085	0.0111	0.0140	0.0097	0.0300	0.0270

*Listings in parentheses indicate unified threads.

†Major diameter of internal threads may extend to a *p*/24 flat.

‡British: effective diameter.

§Minor diameter of external threads may extend to a *p*/8 flat.

Source: Data from American Standard ASA B1.1-1949, published by the American Society of Mechanical Engineers, New York. Values are based on a length of engagement equal to the nominal diameter.

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TABLE 4.8.3 Dimensions and Tolerances for Metric Screw Threads

	External threads						Internal threads				
	Major diameter		Pitch diameter				Minor diameter		Pitch diameter		
Basic thread designation	Maximum	Minimum	Maximum	Minimum	Minor diameteR (flat root), maximum	Minor diameter (rounded root), minimum*	Minimum	Maximum	Minimum	Maximum	Major diameter, minimum
M1.6 × 0.35	1.581	1.496	1.354	1.291	1.202	1.075	1.221	1.321	1.373	1.458	1.600
M2 × 0.4	1.981	1.886	1.721	1.654	1.548	1.408	1.567	1.679	1.740	1.830	2.000
M3 × 0.5	2.980	2.874	2.655	2.580	2.439	2.272	2.459	2.599	2.675	2.775	3.000
M4 × 0.7	3.978	3.838	3.523	3.433	3.220	3.002	3.242	3.422	3.545	3.663	4.000
M5 × 0.8	4.976	4.826	4.456	4.361	4.110	3.869	4.134	4.334	4.480	4.605	5.000
M6 × 1	5.974	5.794	5.324	5.212	4.891	4.596	4.917	5.153	5.350	5.500	6.000
M8 × 1.25	7.972	7.760	7.160	7.042	6.619	6.272	6.647	6.912	7.188	7.348	8.000
M8 × 1	7.974	7.794	7.324	7.212	6.891	6.596	6.917	7.153	7.350	7.500	8.000
M10 × 1.5	9.968	9.732	8.994	8.862	8.344	7.938	8.376	8.676	9.026	9.206	10.000
M10 × 1.25	9.972	9.760	9.160	9.042	8.619	8.272	8.647	8.912	9.188	9.348	10.000
M12 × 1.75	11.966	11.701	10.829	10.679	10.072	9.601	10.106	10.441	10.863	11.063	12.000
M12 × 1.25	11.972	11.760	11.160	11.028	10.619	10.258	10.647	10.912	11.188	11.368	12.000
M16 × 2	15.962	15.682	14.663	14.503	13.797	13.271	13.835	14.210	14.701	14.913	16.000
M16 × 1.5	15.968	15.732	14.994	14.854	14.344	13.930	14.376	14.676	15.026	15.216	16.000
M20 × 2.5	19.958	19.623	18.334	18.164	17.252	16.624	17.294	17.744	18.376	18.600	20.000
M20 × 1.5	19.968	19.732	18.994	18.854	18.344	17.930	18.376	18.676	19.026	19.216	20.000
M24 × 3	23.952	23.577	22.003	21.803	20.704	19.955	20.752	21.252	22.051	22.316	24.000
M24 × 2	23.962	23.682	22.663	22.493	21.797	21.261	21.835	22.210	22.701	22.925	24.000
M30 × 3.5	29.947	29.522	27.674	27.462	26.158	25.306	26.211	26.771	27.727	28.007	30.000
M30 × 2	29.962	29.682	28.663	28.493	27.797	27.261	27.835	28.210	28.701	28.925	30.000
M36 × 4	35.940	35.465	33.342	33.118	31.610	30.654	31.670	32.270	33.402	33.702	36.000
M36 × 2	35.962	35.683	34.663	34.493	33.797	33.261	33.835	34.210	34.701	34.925	36.000

*For reference.

Source: From American National Standard ANSI B1.13-1979, published by the American Society of Mechanical Engineers.

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